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ABSTRACT

Focusing on primary school children, a study investigated whether children can profit from the use of explanatory analogies to acquire information from expository text. Subjects, 24 kindergarteners and 34 second graders in a midwestern town, listened to 4 texts describing relatively unfamiliar topics with or without explanatory analogies. The children were asked to recall the information described in the texts and to communicate this information to another child. They were also asked several inferential questions about the topics. Results indicated that children in the analogy condition recalled and communicated more of the information contained in the texts and were more likely to remember the content units shared by the analogous concepts than the children in the no analogy condition. This effect was stronger for the older children than for the younger children. Although the children made a number of erroneous inferences about the topic, these inferences were not related to the presence of the analogies. Results indicated that analogies can help children acquire information from expository text, presumably because they make it possible for the children to transfer an explanatory structure from a familiar domain to an unfamiliar one. (Eight tables of data and five figures are included, and 44 references are attached.) (MM)

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Technical Report No. 460

EXPLANATORY ANALOGIES CAN HELP CHILDREN ACQUIRE INFORMATION FROM EXPOSITORY TEXT

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Abstract

This paper reports an experiment that investigated whether children can profit from the use of explanatory analogies to acquire information from expository text. Five-year old (N=24) and 7-year old (N=34) children listened to four texts describing relatively unfamiliar topics with or without explanatory analogies. The chil - were asked to recall the information described in the texts and to communicate this information to another child. They were also asked a number of inferential questions about the topics. The children in the analogy condition recalled and communicated more of the information contained in the texts and were more likely to remember the content units shared by the analogous concepts than the children in the no analogy condition. This effect was stronger for the older children than the younger children. Although the children made a number of erroneous inferences about the topic, these inferences were not related to the presence of the analogies. The results of this experiment show that analogies can help children acquire information from expository text, presumably because they make it possible for the children to transfer an explanatory structure from a familiar domain to an unfamiliar one.

EXPLANATORY ANALOGIES CAN HELP CHILDREN ACQUIRE INFORMATION FROM EXPOSITORY TEXT

A question of fundamental interest in educational psychology is how students acquire new knowledge, and, more specifically, how they acquire new knowledge from expository text. Recent research has reaffirmed the importance of prior knowledge in children's thinking, learning and remembering, but a great deal of that work is silent on the acquisition mechanisms that enable new knowledge to be accumulated (e.g., Vosniadou & Brewer, 1987). One mechanism that has been proposed as a possible explanation of knowledge acquisition is learning by analogy. The purpose of the research reported in this paper is to investigate children's acquisition of knowledge from expository text and to determine whether the use of analogies can facilitate children's understanding of the new concepts included in that text.

Analogical Reasoning in Childhood

There has been considerable research on the role of analogies as aids of learning in new domains. Examples of such research can be found in Rumelhart and Norman's (1981) efforts to teach adults aspects of the "Ed" text editor using analogy-based models and in Gentner and Gentner's (1983) investigations of the effects of analogies on the understanding of electric circuits. Several studies have also compared the comprehension and memory of information contained in short expository texts presented with or without analogies (e.g., Hayes & Tierney, 1982; Rigney & Lutz, 1976; Royer & Cable, 1976, Schustack & Anderson, 1979; Simons, 1984) or concrete models (Mayer, 1975, 1976, 1978, 1979a, 1979b; Mayer & Bromage, 1980). Results have shown that analogies can be effective learning aids, but research has been limited so far to adults and older children. Little is known about young children's abilities to use analogies to acquire information from expository text.

This is an unfortunate state of affairs because the answer to this question can have important implications both with respect to expository texts written for young children and with respect to teaching methods. Current surveys of textbooks addressed to elementary school children show that although some figurative language is present in basal reading series, explanatory analogies are almost absent from content area textbooks (e.g., Dixon, Ortony, & Pearson, 1980; Glynn, Britton, Semrud-Clikeman & Muth, in press).

We believe that the reluctance to use analogies in content area textbooks may have its origins in the wide-spread belief that young children cannot reason by analogy. Indeed, some developmental research has shown that children younger than 9 or 10 find it difficult to engage in analogical problem-solving (e.g., Levinson & Carpenter, 1974; Sternberg & Fiftin, 1979; Sternberg & Nigro, 1980), or understand metaphors (e.g., Asch & Nerlove, 196; Cometa & Eson, 1978; Winner, Rosenstiel & Gardner, 1976). However, when materials and tasks appropriate for young children are used, even 4-year olds are found capable of solving 4-term analogies (Alexander, Willson, White, & Fugua, 1987; Gentner, 1977), understanding relational metaphors (Keil, 1986; Vosniadou, Ortony, Reynolds & Wilson, 1984), and solving a problem subsequent to listening to a story where an analogous problem was solved (Brown & Kane, in press; Brown, Kane & Echols, 1986; Holyoak, Junn & Billman, 1984).

In recent work we have argued that children are capable of perceiving similarities between objects, concepts, or events from early on if these similarities are part of children's representations of those entities. What develops, according to this view, is not so much the ability to engage in analogical reasoning per se but the conceptual system upon which this analogical reasoning operates (Vosniadou, 1988; Vosniadou, in press).

It is not only the case that young children can reason by analogy. Analogical reasoning may be a primary mechanism for knowledge acquisition in childhood. It is well documented, for example, that adult novices often engage in analogical types of processes when they reason in unfamiliar domains

where they lack general rules and powerful domain-free problem solving heuristics (e.g., Anderson & Thompson, in press; Ross, in press; Rumelhart & Norman, 1981). We are now becoming increasingly aware that children, universal novices as they are, are also active in relating new information to existing knowledge via analogical types of processes from early on (see Brown & Kane, in press; Mandler, 1983; Vosniadou, 1987; Vosniadou, in press). If this is the case, there is no reason why young children could not profit from the use of explanatory analogies in expository text.

Analogies as Aids of Learning from Expository Text

Researchers generally agree that the process of analogical reasoning involves transfer of a relational structure from a relatively known domain (the source) to another fundamentally similar but less known domain (the topic). This transfer is accomplished by mapping processes which consist of finding the correspondences between the two systems and transferring the relevant information to the topic. There are various proposals as to how this mapping is accomplished. Some researchers argue in favor of a structure-mapping process that relies on structural/relational commonalities as opposed to specific content (e.g., Gentner, in press). Others describe a more pragmatic approach where the mapping is influenced by the system's problem-solving goals (Carbonell, 1983; Holyoak & Thagard, in press).

In the present experiment the similarities between the new concept to be learned (the topic) and the familiar concept from which the analogy was taken (the source) were made explicit in the text; they did not have to be identified. The children's task was to understand the ways in which the new concept was similar to the familiar source and to transfer the similar explanatory structure from the source to their representation of the topic. We expected that the children would be capable of doing this task, and that the assumed information transfer would facilitate the knowledge acquisition process resulting in richer representations of the topic than those based on the expository texts without analogies. A similar hypothesis has been confirmed with research on adults and older elementary school students (Simons, 1984) and is consistent with the results of Mayer's work (1975, 1976, 1978; Mayer & Bromage, 1980) on advance organizers.

Another question of particular interest in this study was the question of inappropriate or unconstrained transfer. Even adults do not always know when they should stop transferring information when the topic is really unfamiliar. Consequently, analogies sometimes result in erroneous or oversimplified representations (e.g., Halasz & Morgan, 1982; Spiro, Feltovitch, Coulson & Anderson, in press). For example, Spiro et al. (in press) mention how medical students often conceptualize blood vessels to be rigid rather than flexible because a common analogy used to teach opposition to blood flow (impedance) uses rigid pipe systems like household plumbing as the source domain.

The problem of inappropriate transfer is more serious in the case of young children whose immature knowledge base often places few constraints on what information should be transferred and what should not. Inappropriate transfer could also occur because of children's alleged tendency to transfer descriptive rather than relational information (e.g., Gentner, 1988, in press). Since descriptive properties are rarely transferred in an analogy such a tendency could produce distorted representations of the topic.

Some of the above-mentioned questions were raised in an exploratory study by Vosniadou and Ortony (1983) where first and third graders' understanding of two expository texts with and without analogies were compared. The children in that experiment retained more information from the texts with analogies than the texts without analogies and did not draw more erroneous inferences than the children in the no analogy condition.

In the present study we wanted to replicate and expand the results of that first exploratory experiment. Four texts covering a wider range of topics were used in this study compared to the previous one. Unlike the previous study, the children were questioned prior to listening to the expository texts to ascertain that they had the relevant prior knowledge of the source domain but not of the topic concept.

Obviously, in order to test the hypothesis that it is easier to build a new representation by transferring an existing structure from a different domain than by constructing it only on the basis of the information contained in the text, we need to know that the relevant structure exists in children's representation of the source but that it is missing from their representations of the topic.

In order to test whether the children understood the similarities between the analogous concepts and could transfer the relevant information spontaneously, we asked them to explain the analogies before they listened to the expository text which contained them. Finally, in order to investigate the effects of the analogy on children's comprehension and memory of the topic we asked the children to recall the texts and also to explain the new concept to another child. We hoped that this "communication task" would encourage children to reveal more of the information they had obtained from the expository text than the recall measure. Finally, slightly younger children were used in this experiment than in the previous one to increase the probability of finding transfer errors.

Method

Subjects

The subjects were 24 kindergarten children, ranging in age from 5.5 to 6.8 years (mean age 5.10), and 34 second grade children, ranging in age from 7.3 to 8.8 years (mean age 7.9). The children attended school in a midwestern town. In each group approximately half of the children were girls and half were boys (kindergarten: 11 girls and 13 boys; second grade: 19 girls and 14 boys). In addition to the children, 18 adult subjects served as a control group.

Materials

The materials consisted of four expository texts on (a) *How an infection heals*, (b) *How the stomach works*, (c) *Termite societies*, and (d) *Dreams*, written in two forms: an analogy condition and a no analogy condition. The same factual information was contained in both conditions except, of course, that the texts with analogies contained an explicitly stated, explanatory analogy. The texts were between 250 and 380 words long. The texts with analogies were between 10 to 50 words longer than their equivalent no analogy conditions. Table 1 shows an example of the text "How an Infection Heals" in the two conditions.

[Insert Table 1 about here.]

The analogies used were the following: (a) An infection is like a war, (b) The stomach is like a blender, (c) Termite societies are like kingdoms, and (d) Dreams are like movies. The main structural/functional similarities between the source and topic concepts which were made explicit in the texts with the analogies are described in Figure 1. This information represents the explanatory structure the children needed to transfer from the source to their representations of the topic.

[Insert Figure 1 about here.]

Procedure

Each child was questioned on 2 out of the 4 topics under investigation, one in the analogy condition and the other with the no analogy condition. The order of presentation of the two conditions was counterbalanced. The mean lapse time between the first and second interview was 40 days. The interview was audio-taped and was later transcribed by the experimenters.

Analogy condition. The children were first asked a question aimed at ascertaining their prior knowledge of the target topic (e.g., "Have you heard the word 'infection' before?" and "Do you know what an infection is?"). Subsequently, all the children were read a one-sentence description of the

topic. For example, in the case of infection they were told that a cold is an infection which is caused by germs entering your body from your mouth or nose. They were also told that substances in your blood called white blood cells protect your body from an infection. Following this short definition the children were presented with a one-sentence analogy about the topic which they were asked to explain (e.g., "What does it mean to say that 'Infection is like War'?). Following the presentation of the analogy, the children were asked a prior knowledge question about the source domain (e.g., "What do you know about war?") and were subsequently provided with a short definition of the source regardless of their prior knowledge level. The interview continued with a series of inferential questions which examined children's beliefs about various properties of the topic (e.g., do white blood cells die, do they feel hungry, are they scared when they attack the germs? etc.). Finally, the topic text containing the explanatory analogy was presented and was read twice by the experimenter. Each child was asked to recall the text and to communicate the information contained in it to another child from the same class.

No analogy condition. The no analogy condition was similar to the analogy condition with the exception that the expository texts did not contain any analogies. In addition, the children were not asked prior knowledge questions about the source domain and were not asked to explain the relevant one sentence analogies.

Adult control. Eighteen adult subjects were asked the inferential questions about the topic. Their answers provided a base line for evaluating the children's answers to those questions. Half of the adult subjects were randomly assigned to the analogy condition and the other half to the no analogy condition. The adults in the analogy condition were told that the questionnaires had been administered to young children to test their comprehension of analogies.

Scoring

All scoring was done on the transcribed data. Children's communications of the topic to another child were transcribed and were treated like recalls. In order to score the information contained in the recalls and communications of the expository texts, the content information for each passage was divided into three kinds of units containing propositional information: (a) analogies, (b) basic content units, and (c) details. The analogies explicitly stated an analogical relationship between the source and the topic, for example, "an infection is like a war," or "the body's soldiers are the white blood cells," and were of course, present only in the passages with analogies. The basic content units carried the main explanatory information, for example, "the white blood cells work their way out of the blood vessels and into the infected area to destroy the germs." This type of information appeared in both conditions but the phrasing was not always identical. For example, the above-mentioned content unit was phrased as follows in the analogy passage: "The white blood cells work their way out of the blood vessels and into the infected area and the fight with the germs is on." The detail units, which also appeared in both passages, contained elaborations of the explanatory information which were not deemed to be crucial to understanding the text, for example, "pus is eventually drained away."

Children's recalls and communications were scored for the amount of basic information they contained by tallying the explanatory content units. Details, analogies, and inferences that the children made on the basis of the information contained in the texts were tallied separately. Agreement was high (97.5%). All cases of disagreement were resolved after discussion.

Results

Prior Knowledge

As Table 2 shows, about half of the 5-year-old children and almost all of the 7 year-old children had heard the words "termites" and "infection." The words "stomach" and "dreams" were known by practically all the children. However, responses to the question "What do you know about (the topic)?" revealed that in most cases the children did not have the structural/functional information

communicated by the analogies (see Figure 1) and described in the expository texts. As shown in Tables 2 and 3, the children mentioned that termites are bugs who live underground, that an infection is a cut or a sore, and that the stomach has food in it. Most of the children knew, however, that dreams are pictures in your mind which you see when you are asleep.

[Insert Tables 2 & 3 about here.]

The children knew considerably more about the source than they knew about the topic, as is shown in Table 4. Most critically, their representations of the source seemed to include the structural/functional information which should be transferred to the topic. More specifically, most children knew that a blender is a machine that cuts food into smaller pieces, said that in a war people fight and shoot each other, and mentioned a King and a Queen living in a castle when hearing the word kingdom. The word 'movies' elicited very similar responses to the word 'dreams' (e.g., they are pictures that you see), indicating that there was not much new information to be carried from the source to the topic, in this case.

[Insert Table 4 about here.]

Although the older children knew more than the younger ones, the age differences in prior knowledge were not statistically significant. There were no significant differences in prior knowledge between the children in the analogy and no analogy conditions.

Interpretations of Analogy

We asked children in the analogy conditions to explain the analogies twice. Before (Phase 1) and after (Phase 2) they listened to the expository text. Their responses were scored as "don't know," "literal/associative," or "relational/correct." Literal/associative explanations revealed various misunderstandings of the analogy, as in: "When a movie is scary you can dream about it!" "Well, movies can show up in your head and people can come to see them in your head." They were common in children's interpretations of the "Dreams are like movies" analogy at Phase 1. A few such responses appeared in the "Termite" and "Infection" passages at Phase 1 as well. Overall, the analogy "Termite societies are like kingdoms" generated the greatest number of correct interpretations at Phase 1, all of which focused on the fact that termites live in big groups and that they may have a leader. All the other analogies were difficult to explain at Phase 1.

We do not know the reasons for this difficulty although we can offer some tentative explanations. As far as the stomach is concerned, the children knew that it contains food but did not think of it as capable of cutting and blending the food because, unlike a blender, the stomach feels soft and tender. In the case of the infection analogy we think that the children did not know enough about white blood cells and bacteria germs to conceptualize white blood cells fighting with bacteria germs. Finally the possibility of dreaming of a movie that one has seen gave rise to many associative interpretations of the analogy "Dreams are like movies," despite the fact that this was one case where the children knew that both movies and dreams are "pictures that you see."

Children's analogy interpretations improved after the presentation of the expository texts which contained them. As can be seen in Tables 5 & 6, at Phase 2 interpretations improved significantly in the case of the analogy "The stomach is like a blender" and "Dreams are like movies" ($p < .05$, Binomial test for related samples with frequency of correct response as the dependent measure (Siegal, 1956). This improvement shows that children who cannot explain an analogy can nevertheless understand it if they are explicitly instructed on the similarities between the two analogs.

[Insert Tables 5 & 6 about here.]

Effects of Analogy on Children's Recall and Communication Data

In order to investigate the hypothesis that the children in the analogy condition would retain more information about the target than the children in the no analogy condition, we compared the mean number of basic content units recalled and communicated under the two conditions. We present the mean number of content units *recalled* for each text in Figure 2 and the mean number of content units *communicated* in Figure 3. A 2 (Age) x 2 (Condition) x 2 (Time of Testing) analysis of variance was conducted on these data.

[Insert Figures 2 & 3 about here.]

Recall. A main effect for condition (analogy better than no analogy) was obtained in the text on Termite Societies, $F(1,22) = 3.78$, $MS = 55.53$, $p < .06$. The main effect for condition was in the expected direction in the text about Dreams, but did not reach significance. The older children seemed to profit more from the analogy texts than the younger children. An Age x Condition interaction resulting from the better performance of the older children in analogy condition was obtained in the text about the Stomach $F(1,21) = 3.92$, $MS_e = 17.03$, $p < .06$, and about Infection $F(1,20) = 4.77$, $MS_e = 23.04$, $p < .04$. Main effects for age were also obtained in the text about Termite Societies $F(1,22) = 13.93$, $MS_e = 104.80$, $p < .001$, Dreams $F(1,20) = 11.95$, $MS_e = 55.860$, $p < .002$), and Stomach $F(1,21) = 17.19$, $MS_e = 74.52$, $p < .001$.

Communication. Main effects for condition (analogy better than no analogy) were obtained in the text about Termite Societies $F(1,22) = 7.04$, $MS_e = 95.52$, $p < .01$, and about the Stomach $F(1,21) = 9.03$, $MS_3 = 52.23$, $p < .01$. An Age x Condition interaction was obtained in the text about the Stomach $F(1,21) = 4.14$, $MS_e = 23.94$ $p < .05$, and Infection $F(1,20) = 11.65$, $MS_e = 53.44$, $p < .01$, again resulting from the better performance of the older children than the younger children in the analogy condition. Main effects for age were obtained for the texts about Termite Societies $F(1,22) = 9.95$, $MS_e = 135.20$, $p < .01$, Dreams $F(1.20) = 9.94$, $MS_e = 51.07$, $p < .01$, and Stomach $F(1,21) = 13.80$, $MSe = 79.77$, $p < .001$. It thus appears that the older children were better able to communicate the information included in the texts to their peers than the younger children, and profited more from listening to the texts with analogies than the younger children.

Recall and communication of the content units present in the source. If analogies help children structure the topic by transferring information from the source, the children in the analogy condition should recall and communicate the particular content units shared by the source and the topic (those appearing in Figure 1) better than the children in the no analogy condition. In order to investigate this hypothesis we compared children's recall and communication of the content units shared by the source and the topic in the texts where a main effect for Condition or a Condition x Age interaction had been obtained (Termite Societies, Stomach and Infection).

As illustrated in Figure 1, the purpose of the analogy "Termite societies are like kingdoms" was to help children understand how a termite society is structured (e.g., that it has a King, a Queen, workers and soldiers), and how segments of this society function (e.g., the soldiers protect the King, Queen and the other termites, the workers work to feed the rest of the society, etc.). The children in the analogy condition recalled and communicated these content units better than the children in the no analogy condition, although statistically significant differences (Fisher Exact Test) were obtained only in a few cases due to the small number of subjects (see Table 7). The content units shared between source and topic in the text about the stomach (that food comes in the stomach, is cut down and is pushed out) and infection (that white blood cells fight with invading germs) were also better recalled and communicated by the children in the analogy condition than those in the no analogy condition.

[Insert Table 7 about here.]

Spontaneous Inferences

Are children in the analogy condition more likely to generate wrong inferences because of indiscriminate transfer of information from the source to the topic? In order to answer this question we first looked at the spontaneous inferences found in children's recalls and communications distinguishing "right inferences" from "wrong inferences" (Table 8). Inferences such as "infections hurt," "infections are bad," "if the germs win the infection gets worse" were considered to be right. Inferences such as "the cells are shooting and firing," "infection is when people die," "red cells turn into powder" were considered to be wrong.

[Insert Table 8 about here.]

A 2 (Age) x 2 (Condition) analysis of variance was performed separately for the immediate recall and communication data. These analyses did not support the hypothesis that the children in the analogy condition were more likely than the children in the no analogy condition to produce erroneous inferences about the topic. The differences found were only age related differences. A main effect for age was obtained in the mean number of right inferences recalled in the text on dreams, $F(1,14) = 5.04$, $MS = 5.76$, $p < .05$, and communicated in the text on termite societies, $F(1,26) = 4.04$, $MS = 57.80$, $p < .05$, resulting from the greater number of right inferences produced by the older children compared to the younger children. A main effect for age was also obtained in the mean number of wrong inferences communicated in the text on infection, $F(1,24) = 4.67$, $MS = 3.44$, $p < .05$, resulting from the greater number of wrong inferences produced by the younger children compared to the older children.

Elicited Inferences

In the case of indiscriminate transfer, the children in the analogy condition should have a higher percentage of erroneous responses to certain inferential questions than the children in the no analogy condition. For example, we should have a higher percentage of *YES* responses to questions like "Do white blood cells wear uniforms?," "Are they scared?," "Are they sorry for killing the germs?" "Do they think that germs are bad?" in the analogy condition than in the no analogy condition.

The results revealed only few differences between the analogy and no analogy conditions on this measure. The 5-year-old children were more likely to say that termites "go to parties" and "get sick" ($p < .05$ for "go to parties," $p < .01$ for "get sick"), and that dreams are real ($p < .01$) in the analogy condition than in the no analogy condition. Some of the differences obtained were not in the expected direction. For example, all the 7-year-olds in the no analogy condition said that the white blood cells "are sorry when they are fighting the germs," whereas only 37% of the 7-year-olds in the analogy condition did so ($p < .001$, Fisher Exact Test).

Responses to the inferential questions were influenced more by differences in age. These differences were particularly noticeable in the inferential questions about termites and about white blood cells and germs. As shown in Figures 4 and 5, the adults were much more likely to agree on what kinds of things termites and white blood cells can and cannot do than the children. In some cases there was also wide disagreement between the adults' and children's attributions of certain properties to white blood cells or termites. For example, the 5-year-old children in our sample were much more likely to think that termites can "go to parties" and "can move to another termite society if they don't like the one they're in" than the adults ($p < .01$ and $p < .01$ respectively). On the other hand, only about 60 to 70% of the 5-year-olds thought that termites "can communicate" compared to 100% of the adults ($p < .01$). In the case of white blood cells, most of the 5- and 7-year-old children but very few of the adults believed that white blood cells can be "scared" ($p < .001$) or "sorry" ($p < .01$), "think that germs are bad" ($p < .01$), or "can decide not to fight" ($p < .01$). The children were, however, less likely than the adults to say that white blood cells are "alive" ($p < .01$). In the case of the inferential questions about dreams, the only

significant difference was that the 5-year-old children were more likely than the adults to say that dreams are real ($p < .002$).

[Insert Figures 4 & 5 about here.]

Discussion

The results of the present experiment demonstrate that analogies can be effective aids of learning from expository text for young children. The children in our sample retained more information when they listened to expository texts with analogies than texts containing the same factual information but without analogies. By questioning the children we were able to determine that the majority of them did not know the critical information about the new concepts conveyed by the analogies and contained in the expository texts (at least in three of the four concepts investigated), although this information was part of their representation of the source analog. We can conclude therefore that the transfer of information that texts with analogies promote results in richer representations of a new concept than those usually derived from texts without analogies.

With the exception of one analogy (termite societies are like kingdoms) the children did not provide adequate explanations of the one phrase analogies at Phase 1 although they were able to do so after they listened to the expository texts that explained them (Phase 2). These results show that children's analogy interpretations are not a good measure of children's ability to understand an analogy when the similarities between the source and topic items are made explicit. Thus, while children are capable, in principle, to see the similarities between two analogous concepts and to transfer information from one to the other spontaneously, this ability improves when the children are explicitly instructed on what to transfer.

The 5-year-old children were able to profit from the analogies in 3 of the 4 concepts investigated (termite societies, stomach and dreams); nevertheless, they were less likely to do so than the 7-year-old children. We do not really understand the reasons for this developmental effect other than to say that it may have to do with the nature of children's knowledge about the source and topic domains and the complexity of the required mappings.

Developmental effects in analogy comprehension have sometimes been attributed to difficulty in transferring relational, as opposed to descriptive information (Gentner, 1988, in press). The results of this experiment did not support this interpretation. Children's explanations of the analogies at Phase 2 show that they readily transferred the relevant relational information. In these explanations the children were, for example, capable of saying that "a stomach is like a blender because it cuts and blends food" and that "an infection is like a war because the white blood cells fight with the germs."

If the children had a propensity to transfer descriptive rather than relational information we should have seen transfer of descriptive properties from the source to the topic domain in their spontaneous and elicited inferences. No evidence for such transfer was found in this experiment. The children who listened to the texts with the analogies did not think that white blood cells look like people, wear uniforms, or carry guns. Spontaneous and elicited inferences involved mostly the transfer of relational information. For example, the children said that you can die from an infection, that you can win an infection, that infections make you hurt, that the blood cells feel sorry when they hurt the germs, that the blood cells think that germs are bad, etc. Although some of these inferences were clearly wrong, they do demonstrate that young children do not hesitate to map relational information from a familiar source to an unfamiliar topic. If anything, children cannot be accused of lack of analogical transfer, but of overgeneralization caused by the absence of constraints in the immature knowledge base. For example, it appears that young children know enough about the blood to be able to infer that it is not possible for white blood cells to wear uniforms but not enough to know that white blood cells cannot think or feel like humans do. In the absence of such constraints children readily transfer this information from the source to the topic.

Of interest is also the finding that the children in the analogy condition did not differ from those in the no analogy condition in the kinds of spontaneous and elicited inferences they drew, although they both differed substantially from the adult subjects on this measure. Unlike the adults, most children attributed feelings, emotions and thoughts to white blood cells and germs, considered dreams to be real, and thought of termites as having human-like volition or intention.

Erroneous inferences of this sort indicate a spontaneous transfer of knowledge from more to less familiar concepts in the children who were in the no analogy condition. Similar transfers of knowledge have been documented by other researchers. For example, Carey (1985) found that children younger than 10 years decide what properties an item has on the basis of its similarity to people. This type of reasoning can produce certain misconceptions which surface when the children are asked key questions. As children acquire more world knowledge they build the constraints needed for more selective transfer. The use of explanatory analogies can promote the differentiation of the analogous concepts if the opportunity is used to illustrate not only their similarities but also their differences.

Overall, the results of this experiment support the position that analogical reasoning is a mechanism of knowledge acquisition available to young children. The use of explicit, explanatory analogies can help children build representations of new concepts which are richer than the ones obtained from information contained in expository texts without analogies. Because these representations are linked with information already existing in the knowledge base, the use of analogies could also increase the probability of knowledge being used in a flexible and creative manner thus avoiding the problem of inert knowledge (Bransford, Franks, Vye, & Sherwood, in press).

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Figure Captions

Figure 1. Structural Correspondence between the two analogies.

Figure 2. Mean number of content units recalled for each expository text.

Figure 3. Mean number of content units communicated for each expository text.

Figure 4. Percent "Yes" Responses to the inferential questions about the text on Termite Societies

Figure 5. Percent "Yes" Responses to the inferential questions about the text on How an Infection Heals.

Table 1

How an Infection Heals: Analogy Condition

analogy 1
(An infection is like a war.) Like a country can be attacked by an enemy, so can your body be attacked by harmful germs./ For example, a cold
2 3 4 5
is an infection / caused by germs / that invade your nose / and often spread
6 7
to your throat./ Or, if you cut yourself,/ harmful germs might enter your
8
skin./ Once they are inside the germs keep on producing more and more
9 10
germs / which damage your body / and cause an infection./
analogy
(Your body fights the infection like a country fights the enemy.) It
11 12
gathers its army of soldiers / and sends it to the attacked area to fight the
13 14
enemy./ The body's soldiers are the white blood cells./ Your blood carries
15
many white blood cells to the infected area./ Because so much blood
16
gathers,/ the infected cut usually appears red and swollen./
detail 17
/Once the extra blood is there,/ the white blood cells work their way out of the blood vessels and into the infected area and the fight with the
18
germs is on./ The first thing the white blood cell soldiers do is surround
19
the enemy / to keep the from multiplying and spreading any further./ The
20
white blood cells form a wall around the germs with their own bodies./
21
/Inside the wall other white cells attack the trapped germs to destroy
22
them./ Meanwhile, the germs keep on producing more and more germs,/ so the
detail 23
fighting is furious/ and many white cells die before the battle is won./ The
24
dead bodies of those white cells and of the dead germs are gathered up in the
detail
infected area and form the white matter called pus,/ which is eventually drained away./
25
/The infection heals when your body has won its fight with the invading
analogy
germs (like a war ends when the country has won its battle with the enemy forces that have attacked it.)

Table 1 (Continued)

How an Infection Heals: No Analogy Condition

(An infection means that some part of your body is not working as well as it should. Bacteria germs are often causing the trouble.) (For example, a cold is an infection / caused by germs / that enter your nose / and spread to your throat./ Or, if you cut yourself,/ harmful germs might enter your skin./ Once they are inside, the germs keep on producing more and more germs / which damage your body / and cause an infection./

/Your body deals with an infection by gathering a lot of blood / and sending it to the infected area to destroy the harmful germs./ The body's means of dealing with an infection are especially the white blood cells./

The white blood cells are found in the blood./ Your body brings a lot of blood carrying many white blood cells to the infected area./ Because so much blood gathers,/ the infected cut usually appears red and swollen.)

(Once the extra blood is there,) the white blood cells work their way out of the blood vessels and into the infected area to destroy the germs./ The first thing the white blood cells do is surround the germs / to keep them from making more and more germs and from spreading any further./ The white blood cells form a circle around the germs./ Inside the circle other white cells attack the germs to destroy them./ Meanwhile, the germs keep on producing more and more germs,/ so the white cells' job is a hard one / and many white cells are themselves destroyed before they clear out the germs./ The white cells and germs that are destroyed are gathered up in the infected area and form the white matter called pus,/ which is eventually drained away./

/The infection heals when your body has destroyed the germs./

Table 2

Percent Responses to the Question "Have you heard that word before?"

	Termites	Infection	Stomach	Dreams
5-year-olds				
Analogy	50	50	83	100
No analogy	33	50	83	100
7-year-olds				
Analogy	75	100	100	100
No analogy	80	75	100	100

Table 3

Percent Responses to the Question "What do you know about (the topic)?

	5-year-olds		7-year-olds	
	Analogy	No Analogy	Analogy	No Analogy
Termites are bugs or animals; they live underground	17	50	60	60
An infection is a cut or a sore	50	33	100	25
The stomach has food in it	33	66	88	100
Dreams are pictures in your mind which you see when you are asleep	100	83	88	88

Table 4

Percent Responses to the Question "What do you know about (the source)?"

	5-year-olds	7-year-olds
Kingdoms		
Where King & Queen and other people live	50	50
Big place/castle with lots of people	50	12
War		
people fight/shoot	50	100
Blender		
something (a machine) that cuts/blends food	66	87
Movies		
shows/pictures that people see/watch T.V., theatre)	50	87
something that you see like a play	50	12

Table 5

Percent Responses to the Question "What does it mean to say that (analogy)?" Before Listening to the Expository Text Which Contained Them (Phase 1)

	A Termite Society is like a Kingdom		A Stomach is like a Blender		Dreams are like Movies		Infection is like War	
	5	7	5	7	5	7	5	7
Don't Know	33	25	67	67	33	25	67	50
Literal/Associative	17	0	0	0	50	38	17	0
Relational/Correct[a]	50	75	33	33*	17*	38*	17	50

*Significant pre-post differences at $p < .05$ level, Binomial test for related samples

[a]Relational/correct interpretations for

Termite societies are like kingdoms: They live in big groups, they have a King and Queen, or they have a leader.

A stomach is like a blender: Food goes in it and it blends.

Dreams are like movies: They are pictures or stories; they are not real.

An infection is like a war: They fight to get it away; it hurts in both.

Table 6

Percent Responses to the Question "What does it mean to say that (analogy)" after listening to the Relevant Expository Text (Phase 2)

	A Termite Society is like a Kingdom		A Stomach is like a Blender		Dreams are like Movies		Infection is like War	
	5	7	5	7	5	7	5	7
Don't Know	0	0	17	0	0	0	50	0
Literal/Associative	17	12	0	0	0	0	0	0
Relational/Correct[a]	83	88	67	100*	100	100*	50	100

*Significant pre-post differences at $p < .05$ level, Binomial test for related samples

[a]Relational/correct interpretations for

Termite societies are like kingdoms: They live in big groups, they have a King and Queen, or they have a leader.

A stomach is like a blender: Food goes in it and it blends.

Dreams are like movies: They are pictures or stories; they are not real.

An infection is like a war: They fight to get it away; it hurts in both.

Table 7

Percent of Content Units Shared by the Source and Target Domains Present in The Recall and Communication Data

"The Stomach is like a Blender"	Immediate Recall 7-year-olds A	NA	Communication 7-year-olds A	NA
Breaks down food	.55	.62	.44	.50
Food comes in	.44	.12	.00	.25
Food is cut down	.33	.12	.44	.00*
Food is pushed out	.33	.12	.22	.00

"Infection is Like War"	Immediate Recall 7-year-olds A	NA	Communication 7-year-olds A	NA
White blood cells and germs fight	.38	.12	.50	.12
White blood cells win	.63	.25	.38	.12
Infection heals	.38	.00	.38	.00

"Termite Societies are like Kingdoms"	Immediate Recall 5-yr-olds A	NA	7-yr-olds A	NA	Communication 5-yr-olds A	NA	7-yr-olds A	NA
Have King & Queen	.33	.00	.87	.70	.66	.33	.75	.70
Have Soldiers	.66	.00*	.62	.10	.33	.00*	.87	.40*
Have workers	.66	.00*	.75	.30*	.66	.00*	.50	.10
Queen has baby termites*	.00	.00	.75	.70	.00	.00	.12	.50
Soldiers protect	.33	.00	.62	.20	.16	.00	.62	.00*
Workers feed	.33	.00	.50	.20	.33	.00	62	.30
Live in Termite Mound	.33	.00	.50	.20	.16	.16	.25	.10

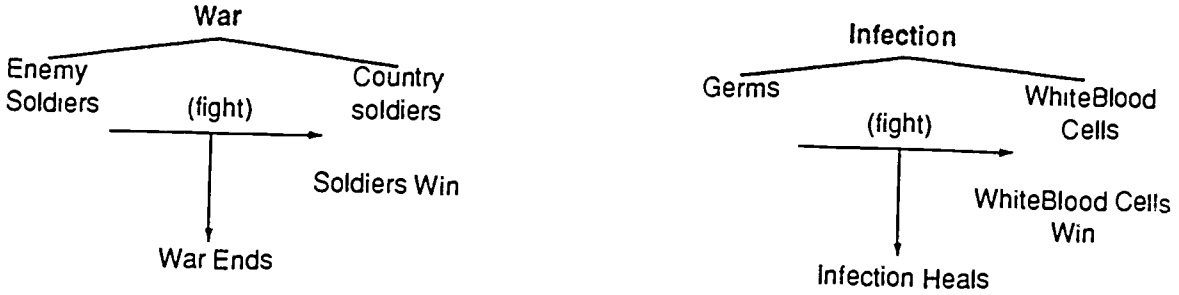
*Significant analogy vs. no analogy differences, $p < .05$, Fisher Exact Test.

Table 8

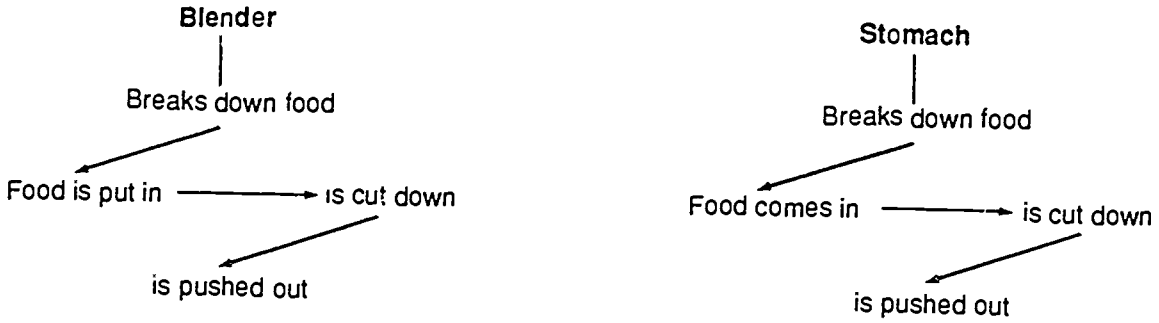
Mean Number of Spontaneous Inferences

	Infection		Termite Societies		Stomach		Dreams	
	Rec.	Comm.	Rec.	Comm.	Rec.	Comm.	Rec.	Comm.
Right Inferences								
5-year-olds								
Analogy	.83	2.50	.33	.16	.00	.16	.33	3.00
No Analogy	1.80	1.50	1.33	.50	.33	.16	.33	1.50
7-year-olds								
Analogy	1.38	3.38	2.25	2.37	.87	2.62	1.25	.62
No Analogy	1.00	1.75	1.37	2.25	.50	.87	1.25	1.25
Wrong Inferences								
5-year-olds								
Analogy	.50	1.30	1.00	.83	1.67	1.30	.83	.00
No Analogy	.83	.83	.50	.33	1.30	.33	.50	.16
7-year-olds								
Analogy	.12	.00	2.37	1.51	.25	.00	.12	1.25
No Analogy	.37	.75	.70	2.12	.37	1.25	.25	.37

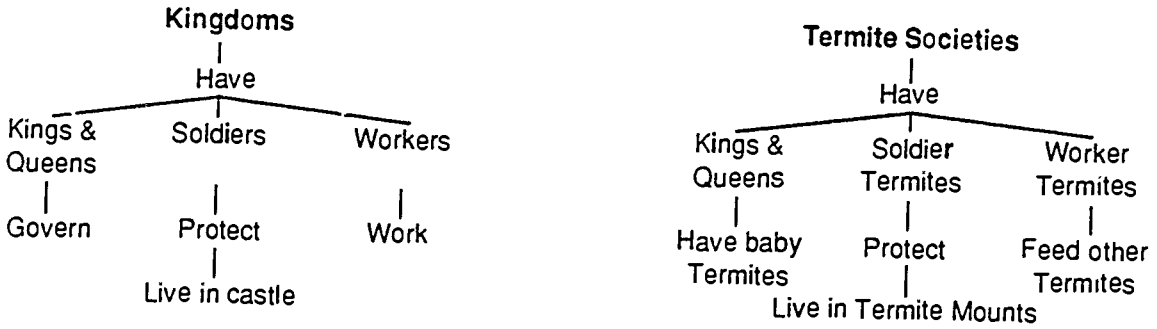
An Infection is like a War



The Stomach is like a Blender



Termite Societies are like Kingdoms



Dreams are like Movies

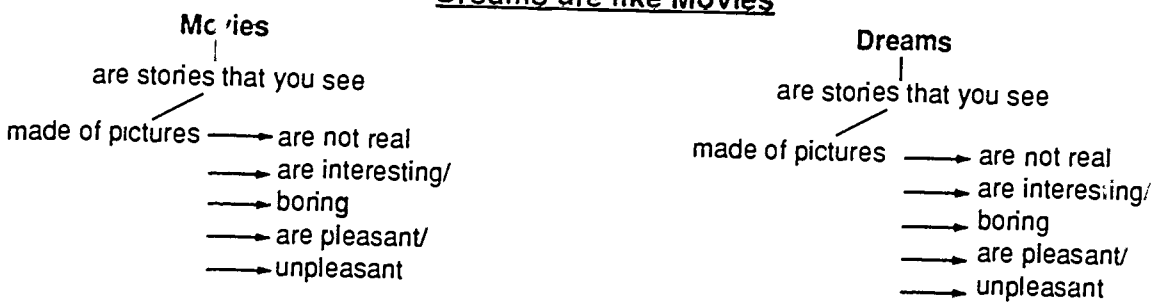


Figure 1

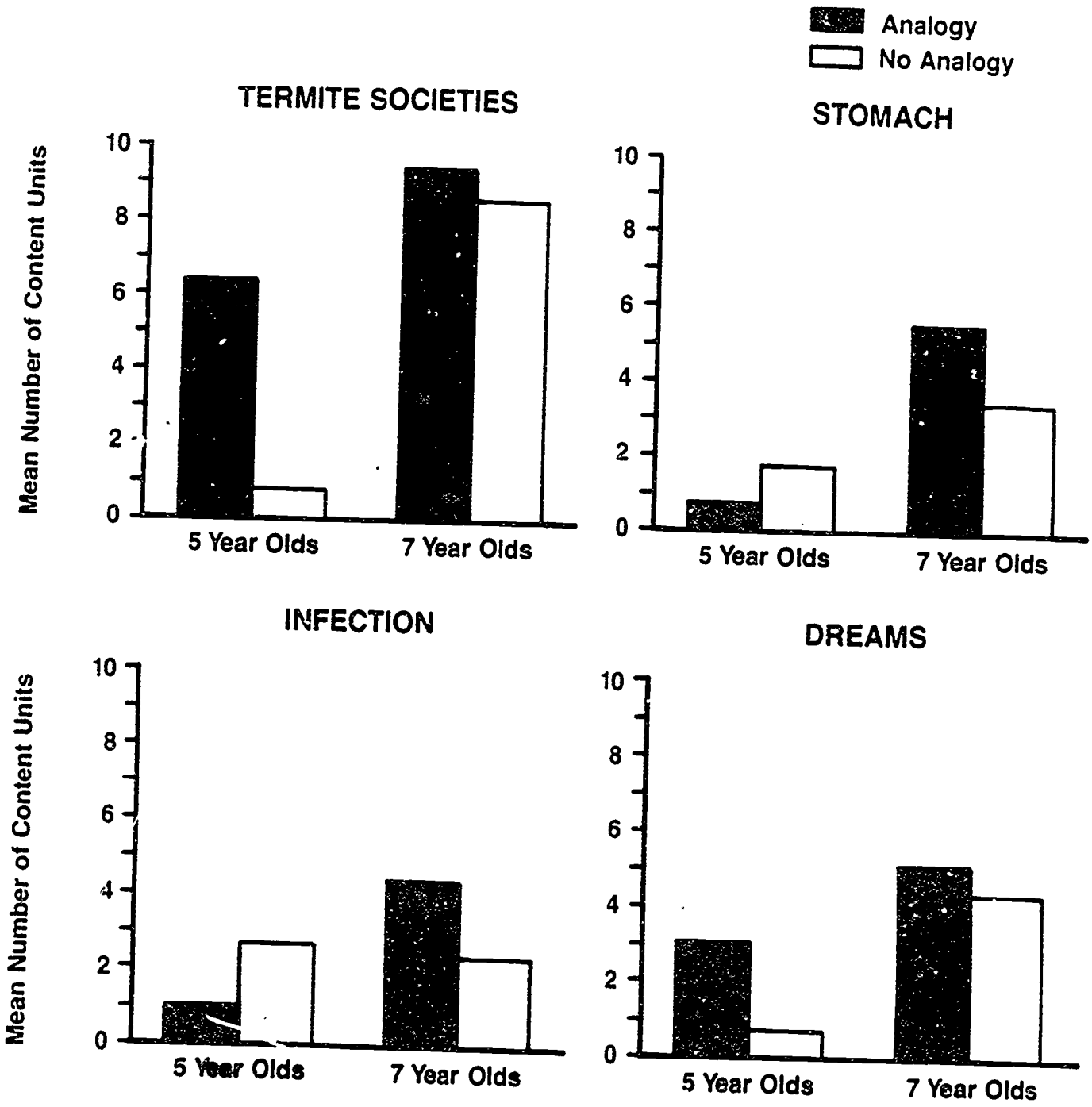

Analogy
No Analogy
TERMITE SOCIETIES
STOMACH
INFECTION
DREAMS
Mean Number of Content Units
Mean Number of Content Units
0
2
4
6
8
10
5 Year Olds
7 Year Olds

Figure 2

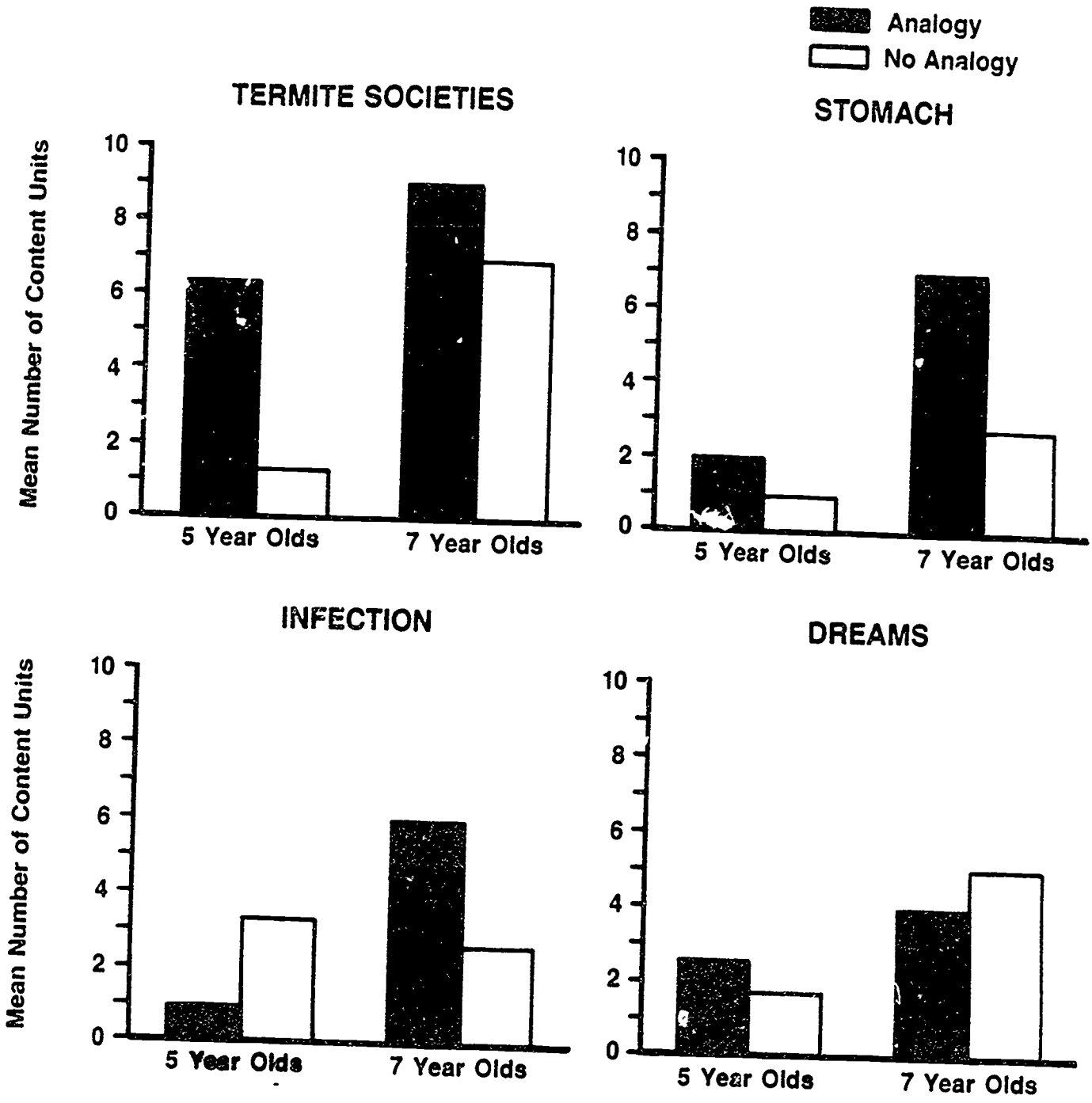
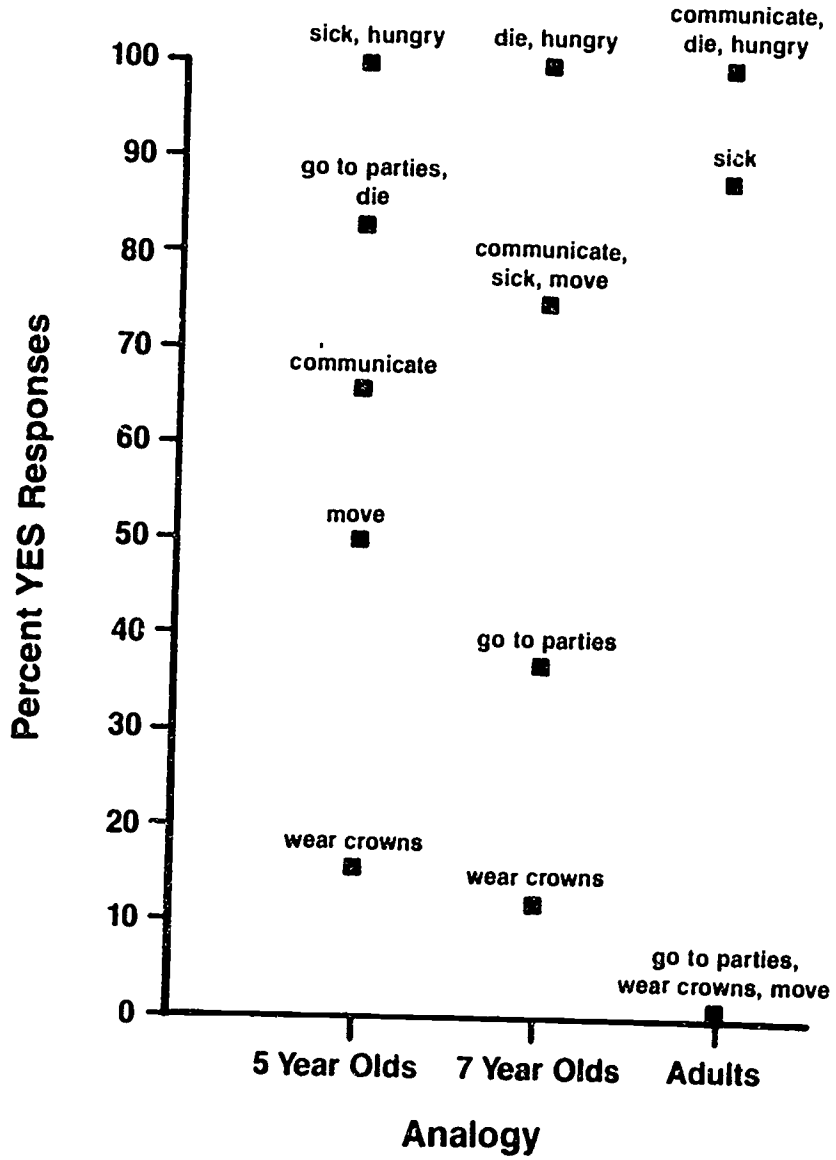

Analogy
No Analogy
TERMITE SOCIETIES
STOMACH
INFECTION
DREAMS
Mean Number of Content Units
Mean Number of Content Units
10
8
6
4
2
0
5 Year Olds
7 Year Olds

Figure 3


Percent YES Responses
100
90
80
70
60
50
40
30
20
10
0
sick, hungry
die, hungry
communicate, die, hungry
go to parties, die
sick
communicate, sick, move
communicate
move
go to parties
wear crowns
wear crowns
go to parties, wear crowns, move
5 Year Olds
7 Year Olds
Adults
Analogy

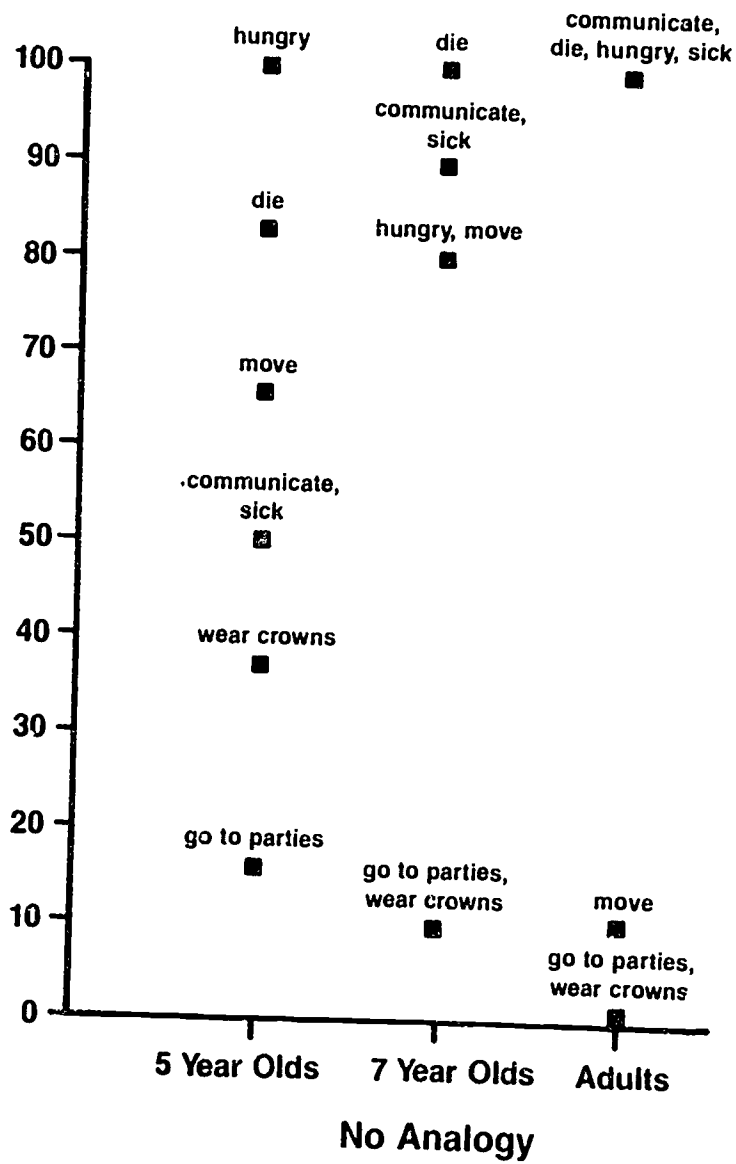
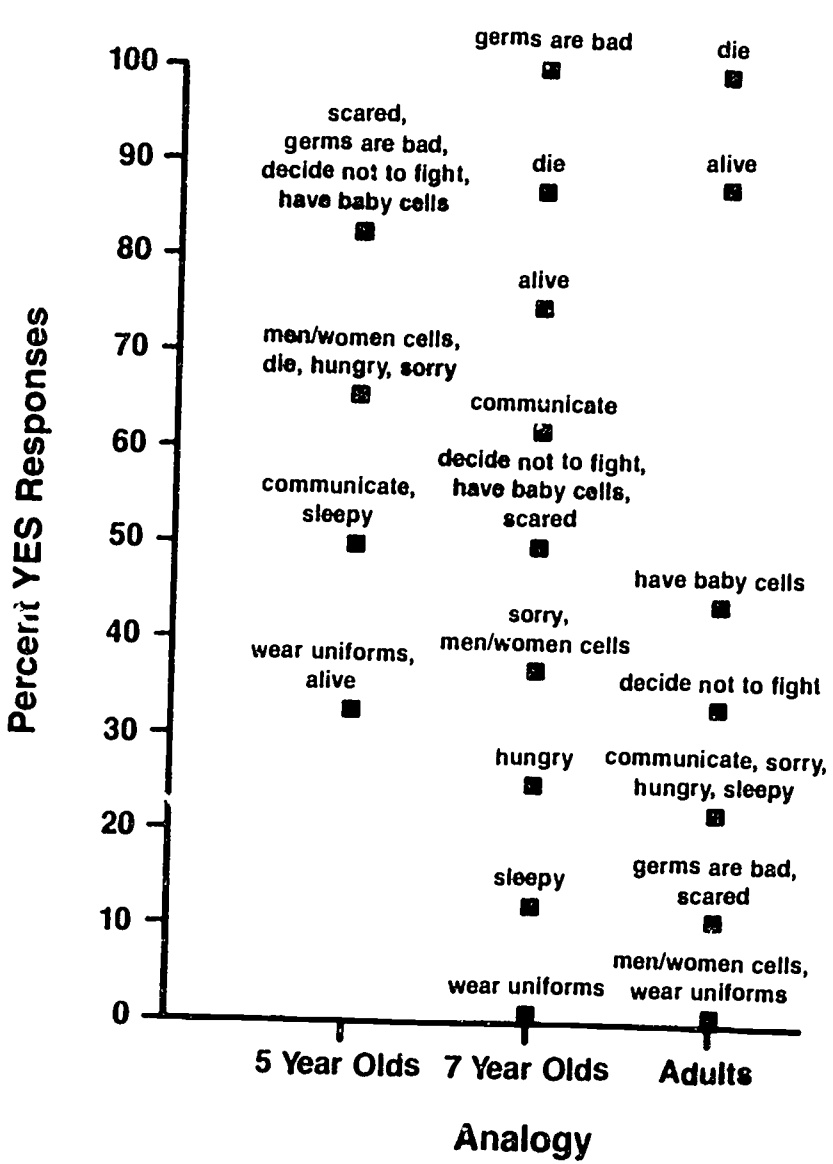

100
90
80
70
60
50
40
30
20
10
0
hungry
die
communicate, die, hungry, sick
communicate, sick
die
hungry, move
move
communicate, sick
wear crowns
go to parties
go to parties, wear crowns
move
go to parties, wear crowns
5 Year Olds
7 Year Olds
Adults
No Analogy

Figure 4


Percent YES Responses
100
90
80
70
60
50
40
30
20
10
0
germs are bad
die
scared, germs are bad, decide not to fight, have baby cells
die
alive
alive
men/women cells, die, hungry, sorry
communicate
communicate, sleepy
decide not to fight, have baby cells, scared
have baby cells
sorry, men/women cells
wear uniforms, alive
decide not to fight
hungry
communicate, sorry, hungry, sleepy
sleepy
germs are bad, scared
men/women cells, wear uniforms
wear uniforms
5 Year Olds
7 Year Olds
Adults
Analogy

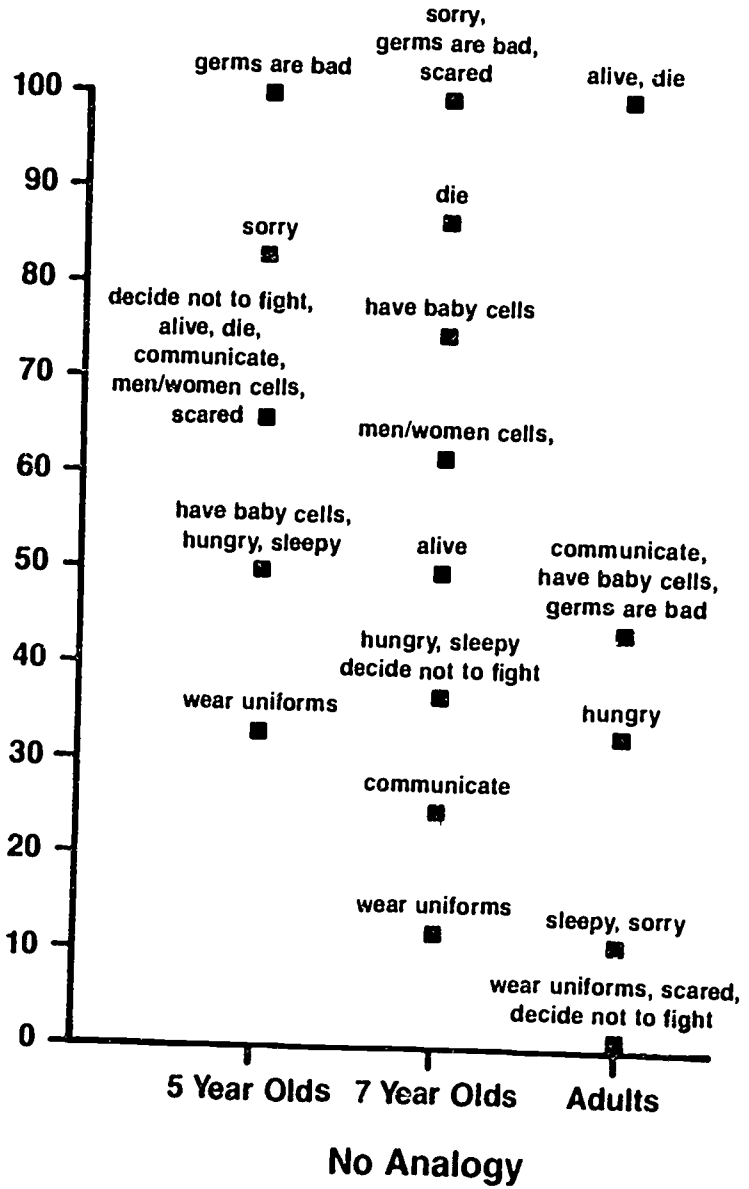

100
90
80
70
60
50
40
30
20
10
0
sorry, germs are bad, scared
germs are bad
alive, die
die
sorry
decide not to fight, alive, die, communicate, men/women cells, scared
have baby cells
men/women cells,
have baby cells, hungry, sleepy
alive
communicate, have baby cells, germs are bad
hungry, sleepy decide not to fight
wear uniforms
hungry
communicate
wear uniforms
sleepy, sorry
wear uniforms, scared, decide not to fight
5 Year Olds
7 Year Olds
Adults
No Analogy

Figure 5